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(54) Magnetic resonance apparatus and methods.

(57) A magnetic resonance apparatus includes a gantry (A) an incorporating a magnet (12) which generates a uniform magnetic field in a thin (typically under 15 cm thick) imaging volume (10). Gradient coils (30) and radio frequency coils (20) transmit radio frequency and gradient magnetic field pulses of conventional imaging sequences into the imaging volume. A patient support surface (42) moves a patient continuously through the imaging volume as the pulses of the magnetic resonance sequence are applied. A tachometer (52) monitors movement of the patient. A frequency scaler (54) scales the frequency of the RF excitation pulses applied by the transmitter (22) and the demodulation frequency of the receiver (26) in accordance with the patient movement such that the selected slice moves in synchrony with the patient through the imaging volume. The slice select gradient is indexed after magnetic resonance signals to generate a full set of views for reconstruction into a two-dimensional image representation of the slice are generated. The views for each slice are reconstructed (28) into a three-dimensional image representation that is stored in a memory (60). By using rapid imaging techniques, such as echo-planar techniques which can generate a two-dimensional image of a slice in 150 milliseconds, a three-dimensional diagnostic image of a section of a subject one metre long can be generated in less than 2 minutes.

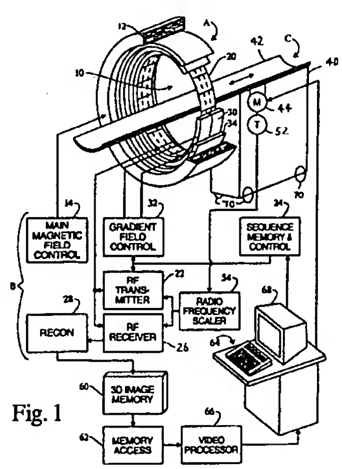

Fig. 1

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This invention relates to the magnetic resonance apparatus and methods. It finds particular application in conjunction with magnetic resonance diagnostic imaging apparatus and methods and will be described with particular reference thereto.

In many medical diagnostic procedures, it is desirable or even necessary to generate an image representation of a relatively large volume of the subject. In prior art magnetic resonance imagers, the imaging volume is generally limited to a sphere within which the primary magnetic field is temporally invariant and uniform. Prior art magnetic resonance imaging systems typically have required a magnetic assembly with a patient receiving bore that is at least 1.5 meters long in order to provide a uniform imaging volume of about 40 cm in diameter. One disadvantage of these systems is that very large magnets and magnet assemblies are required. These very large magnet assemblies have several drawbacks including their large size, immense weight, and high cost. Not only are the magnets themselves expensive, but so is the large size related equipment for generating gradient magnetic fields, RF pulses, and the like.

Another disadvantage of the prior art magnetic resonance imagers is that they can only image a limited portion of the subject. Whole body scans are not impossible. Stretching the uniform magnetic field volume longitudinally adds significantly to the size and cost of the magnetic resonance scanner. Conducting several volume scans with the patient reposited between each one creates image registration problems.

One solution to these problems has been to use spiral CT scanners. Spiral CT scanners are not only much less expensive than conventional magnetic resonance equipment, but also enable the imaging volume to be greatly elongated. In addition to poor soft tissue contrast as compared to magnetic resonance imaging, spiral CT scanners have several other drawbacks. First, the data is collected along spirals which tends to skew the slices, introduce partial volume artifacts, and otherwise degrade the resultant image data. Further, magnetic resonance is preferable for distinguishing many types of tissue, particularly soft tissue and blood. Spiral CT scans to image the patient's circulatory system commonly require the infusion of a contrast agent into the blood. The contrast agent, which has good x-ray stopping power, is then imaged rather than the blood itself.

Another problem with spiral CT scanners resides in the heavy loading of the x-ray tube. Running the x-ray tube continuously for many slices places a great thermal load on the tube. Significant problems are encountered in removing excess thermal heat from the tube. Damage from unremoved excess thermal energy leads to premature x-ray tube failure or at least a very short x-ray tube life.

The present invention contemplates a new and improved magnetic resonance apparatus and method which enables a larger volume to be imaged with simpler, less-expensive equipment.

According to one aspect of the invention there is provided a magnetic resonance apparatus comprising: a patient receiving region; a main magnetic field means disposed around the patient receiving region for generating a main magnetic field which is uniform and temporally constant within an examination volume in the patient receiving region; a radio frequency coil disposed around the examination volume; and a patient support and transport means for supporting a patient in the examination volume during a magnetic resonance examination; characterised in that the examination volume is thin in a direction parallel to the axis of the patient receiving region; and the patient support and transport means moves the patient axially through the examination volume during a magnetic resonance examination.

Normally the apparatus further includes a gradient coil assembly disposed around the radio frequency coil for creating gradient magnetic fields along orthogonal directions in the examination volume.

Preferably the patient receiving region is cylindrical and the examination volume is a cylinder at least 45 cm in diameter and less than 15 cm thick.

The invention also provides a method of magnetic resonance imaging comprising: creating a uniform, temporally constant magnetic field in a thin imaging volume; moving a subject through the thin imaging volume; while the subject is moving through the imaging volume, exciting and manipulating magnetic resonance in a selected slice of the subject that is in the imging volume and receiving magnetic resonance signals from the selected slice, the imaging volume having a thickness of at least twice the selected slice thickness and less than 15cm in the direction of moving the subject; and reconstructing the magnetic resonance signals from a plurality of slices into an image representation.

In a preferred method according to the invention the step of exciting and manipulating magnetic resonance and receiving magnetic resonance signals from the selected slice includes applying a slice select gradient along the direction of moving the subject and the method further includes shifting the selected slice relative to the imaging volume such that the selected slice remains substantially fixed relative to the subject. The selected slice shifting step suitably comprises incrementing a frequency of the received resonance signals.

Apparatus and methods in accordance with the invention will now be described, by way of exam-

ple, with reference to the accompanying drawings in which:-

Figure 1 is a diagrammatic illustration of the apparatus;

Figure 2 is a diagrammatic illustration of a centric phase encoding scheme used in one method in accordance with the present invention;

Figure 3 is a diagrammatic illustration showing in more detail part of the apparatus of Figure 1; and,

Figure 4 illustrates an alternative form of apparatus which uses a permanent magnet.

Referring to Figure 1, the apparatus includes a gantry A which is operated by an electronic processing and control circuit B to excite and manipulate magnetic resonance in a thin imaging volume 10 that is only 2-20 slices thick. The processing and control circuit processes resultant resonance signals from the imaging volume into image representations. A patient transport assembly C moves a patient through the imaging volume during the imaging process.

A main magnet assembly 12, preferably a self-shielded superconducting magnet assembly, generates a primary magnetic field which is temporally constant and uniform in the thin imaging volume **10**. In the preferred embodiment, the imaging volume **10** is a thin disk, about 45 cm or more in diameter, transverse to the longitudinal direction. Preferably, the thin volume **10** is sufficiently wide that about 10-20 parallel slices can be generated within the imaging volume **10**. This enables the scanner to be used for brain scans and obtain traditional volume image representations representing about a 15 cm thick slab through the brain without moving the patient. However, it is to be appreciated, that an imaging volume **10** which is twice the thickness of the maximum available slice is satisfactory. A width of two slices is sufficient to image an indefinite length of the patient when the patient is being moved continuously through the examination region. A main magnetic field control means **14** controls the main magnet assembly **12**. For a superconducting magnet assembly, the magnetic field control **14** is used to ramp up the magnetic field. For a resistive main magnet, the main magnetic field control **14** not only turns on and turns off the main magnet, but also maintains a uniform current flow.

A radio frequency coil **20** surrounds the imaging volume **10**. The RF coil is preferably relatively narrow in the longitudinal direction and shaped for (1) transmitting magnetic field signals substantially exclusively into the imaging volume **10** and (2) receiving radio frequency signals substantially exclusively from the imaging volume. Preferably, a radio frequency shield surrounds the RF coil **20** to prevent radio frequency signals from being irradiated radially outward and to render the radio frequency coil more insensitive to radio frequency signals from outside the imaging volume. A radio frequency transmitter **22** selectively supplies radio frequency current pulses to the radio frequency coil to cause radio frequency pulses to be transmitted into the volume region for exciting and manipulating magnetic resonance. A magnetic resonance imaging sequence memory and control **24** controls the radio frequency transmitter **22** to control the timing and amplitude of the radio frequency pulses to implement any one of a large plurality of conventional magnetic resonance imaging or spectroscopy sequences. A radio frequency receiver 26 is also connected with the radio frequency coil for demodulating radio frequency signals, particularly magnetic resonance signals from within the imaging volume 10 to generate a plurality of magnetic resonance views corresponding to each imaged slice. A reconstruction processor 28 reconstructs the views corresponding to each slice into a two-dimensional image representation using a Fourier transform algorithm. Alternately, each view can be a projection at a different angle, which views are reconstructed with a projection CT-type algorithm. When the patient is moving at a constant speed, as discussed below, a conventional spiral CT reconstruction scheme is used.

A gradient coil assembly 30 operates under control of a gradient field control means 32 to generate magnetic field gradients in the imaging volume. More specifically, the gradient field control 32 supplies current to the gradient coils 30 to cause magnetic field gradients along the longitudinal axis (slice select gradients) and along mutually orthogonal axes transverse to the longitudinal direction (read and phase encode gradients). The magnetic resonance imaging sequence memory and control 24 causes the gradient control 32 and the radio frequency transmitter 22 to apply coordinated radio frequency and gradient pulses of conventional sequences such that resonance is limited to a selected slice orthogonal to the longitudinal direction for each view. Active gradient shield coils 34 are disposed around the gradient coils 30 to limit the gradient magnetic field substantially to the imaging volume 12.

A patient transport means C includes a gantry 40 that supports a patient or other subject within the examination region. The patient gantry 40 includes a patient supporting surface 42 and a motor and gear assembly 44 for continuously moving the patient supporting surface **42** longitudinally through the imaging volume at a selectable velocity. It is to be appreciated, that the continuous longitudinal movement of the patient will cause each view from the radio frequency receiver **26** to represent a slightly shifted slice if the slice select gradient

remains constant in each repeat of the imaging sequence. If the patient is moved sufficiently slowly, preferably less than 3/4 of a slice width before all views of an image are collected, satisfactory images can be obtained nonetheless.

With reference to FIGURE 2, motion artifacts due to the moving patient tend to be highly pronounced in the views with the highest frequency phase encoding. Accordingly, the high frequency phase encoding views in both the positive and negative direction are collected contiguously in a high frequency view region **46**. Progressively lower frequency views are taken contiguous to the immediately preceding and following high frequency views in temporal regions **48**. The low frequency views **50** are furthest displaced from the high frequency views. As illustrated in FIGURE 2, the lowest or central-most views are taken at the beginning and end of the scan. In a 128 view image set in which the highest positive phase encode frequency view is **1**, the highest negative phase encode frequency view is 128, and the central or zero phase encode view is **64**, a suitable view order is: 1, 128, 2, 127, 3, 126, ...

In one alternate embodiment, the low frequency or central views are shared by contiguous slices for greater processing efficiency.

Preferably, the frequency of the RF excitation and refocusing is scaled in coordination with movement of the patient such that the position of the selected slice remains constant with respect to the moving patient for all views even as the selected slice shifts axially through the imaging volume. To this end, a patient motion and sequence timing coordinating means, such as a tachometer **52** is connected with the patient support moving assembly **44** to provide signals indicative of movement of the selected slice through the imaging volume. A frequency scaling means **54** adjusts the RF transmitter **22** such that the RF excitation frequency and the RF demodulation frequency vary slightly with each view when the subject is moving through the imaging volume. The effect of this is to move the selected slice with the moving patient, so that it is fixed relative to the patient. Alternatively, the clock of the sequence memory and control **24** may control the motor **44** such that the patient support **42** is controlled to move in coordination with the imaging sequence.

In one embodiment, the images are rendered insensitive to variations in blood flow during the cardiac cycle by recording the cardiac waveform (from EKG) and analyzing it in a computer to calculate patient support movement speed such that the patient moves one slice thickness per integer number of heartbeats (typically one or two). Preferably, the clock of the sequence memory and control **24** is adjusted to control the sequence timing and the motor **44** to move the patient support **42** at the calculated speed. RF frequency is scaled linearly with time during the acquisition to fix the selected slice to the moving patient, as described in the previous paragraph. By this means, synchronization of acquisition and slice position with both the cardiac cycle and the movement of the patient support is accomplished.

As the two-dimensional image of each slice is reconstructed with either Fourier or projection reconstruction algorithms, it is stored in a three-dimensional image memory **60**. This creates a three-dimensional image representation in which the z-axis resolution is determined by the speed of patient transport, the thickness of the image slice, and the duration required to collect the views for reconstructing each two-dimensional image representation. The x and y-axis resolutions are determined by the number of differently phase encoded views and the frequency resolution. The voxels are rectangular prisms that may have different dimensions along all three axes. A memory access means **62** under control of an operator control panel **64** selectively accesses the voxel values of the three-dimensional image memory **60** to retrieve selected two-dimensional image representations. Transverse, sagittal, coronal, oblique, 3D, and other image representations, as are conventional in the art, are retrieved from the three-dimensional image memory **60** and converted by a video processor **66** into appropriate format for display on a video monitor **68**. The operator also uses the operator control panel **64** for selecting among the multiplicity of available imaging sequences and imaging sequence parameters (repeat time, number of phase encode steps, etc.) which the magnetic resonance imaging sequence memory and control **24** implements. The operator control panel is further used for controlling the patient moving assembly **44** for controlling the speed with which the patient is moved through the examination volume **12**.

For greater patient processing efficiency, the gantry **40** preferably has wheels **70** or the like which enable it to be moved. This enables the subject to be moved between the disclosed magnetic resonance apparatus and other diagnostic scanners, such as CT, SPECT, ultrasound, or the like. This portability further enables one patient to be prepared on one gantry in a preparation room while another patient is undergoing examination on another gantry.

Various types of diagnostic imaging procedures can advantageously be performed with this system. For example, the apparatus can be run in a shadowgraphic survey mode in which the equivalent of a shadowgraphic film x-ray is taken in a plane parallel to the patient support surface **42**. The patient is moved continuously and rapidly

through the imaging volume. For each slice, a view is generated with no phase encoding but which is frequency encoded with a frequency encode or read gradient in a horizontal direction. The "image" for each slice is a one-dimensional image which represents the projection in a vertical direction. When the one-dimensional images for the slices along the entire length of the patient are assembled, a two-dimensional projection image analogous to a shadowgraphic film x-ray is generated. Such a projection survey image is advantageously used to identify regions of the patient for further imaging and study, further positioning of the patient, contrast adjustments, and the like.

As another option, a two-dimensional image representation is generated for each slice using an echo-planar imaging technique which enables each two-dimensional slice image to be generated in about 150 milliseconds. The time to generate each two-dimensional image will, of course, vary with the resolution of the resultant image. However, in a relatively coarse mode (relatively few views per image), at least six two-dimensional slice images can be generated per second. This enables an image to be generated in substantially real time. Such images are potentially valuable for magnetic resonance fluorscopy and other applications.

In another application, flow imaging techniques are utilized. That is, a conventional magnetic resonance sequence is selected which causes the value of each pixel of the slice image to vary with the velocity of the corresponding tissue. In this manner, an image is generated in which gray scale, color, or the like is indicative not of tissue type, but of tissue velocity. Imaging sequences designed for imaging blood can be used concurrently such that images depicting both blood and blood flow velocity of an imaged volume are generated. This technique can be used to measure blood flow through various regions of the body, e.g. the legs for measuring thrombosis. The technique can also be used for measuring or monitoring the patient's cardiac cycle. A traditional EKG measures each time the heart beats, but does not indicate whether or how much blood was pumped with each cycle. The present technique can be utilized to measure the fluid actually pumped by the heart in each beat.

The rapid imaging time, particularly when using echo-planar imaging sequences, is ideally suited for motion studies. Because the imaging volume **10** is so thin, the volume within which the uniform field is created is relatively small. The imaging bore can be larger in diameter than today's conventional magnetic resonance imaging equipment while still effecting a significant decrease in the size and power consumption of the magnet **12** and the other described hardware. A larger bore enables the patient to move an imaged joint without interference from the bore of the imager. Free patient movement is also facilitated by the relatively short axial dimension of the bore. The combination of space for patient movement and rapid imaging, particularly with echo-planar techniques, is ideal for generating a series of volume images of an examined joint as the joint is flexed.

This system is also advantageous in shock and trauma examinations. When a patient is suffering from shock, the physician only has about 3 minutes to work. By using a relatively coarse pixel resolution, a three-dimensional scan of the entire patient can be made in under 3 minutes. This rapid scan technique is also advantageous for rapid screenings for preselected conditions. For example, a magnetic resonance imaging sequence and parameters are selected which are particularly sensitive to a selected condition such as tuberculosis, a selected type of cancer, or the like, and the rapid survey technique is run to locate any regions of the body which require further examination. Because such survey scans can be run in under 3 minutes, the technique finds utility for screening large numbers of people for a specific condition.

With reference to FIGURE 3, the gantry assembly **A** including the main magnet, gradient, and radio frequency coils, is mounted to a gantry **80** for selectively moving the imaging volume **10**. More specifically, the gantry **80** includes wheels **82** or the like which enable the entire assembly to be transported to other locations.

The gantry **80** further includes a means **86** for changing the angular orientation of the thin imaging volume **10**. In the illustrated embodiment, the gantry **A** is pivotally mounted to support arms which carry a motor and gear box assembly for driving the gantry **A** to rotate. Preferably, this enables the gantry to be positioned with the imaging volume in a horizontal plane. A means **88** is provided for causing relative vertical movement between the imaging volume **10** and a standing patient. In the illustrated embodiment, the means **88** includes a drive screw and motor for moving the gantry supporting arms vertically. However, an elevator assembly for raising and lowering the standing patient are also contemplated.

With reference to FIGURE 4, the present invention is also applicable to permanent magnet systems. The gantry assembly **A'** includes a permanent, horseshoe-shaped magnet **100** which has pole faces **102** disposed on opposite sides of a thin, generally rectangular imaging volume **10'**. Gradient coils **30'** surround the imaging volume for selectively causing magnetic field gradients thereacross. Radio frequency coils **20'** are disposed adjacent the imaging volume for transmitting radio frequency pulses into and receiving radio

frequency magnetic resonance signals from the imaging volume **10'**. A patient support and transporting means **C'** is driven by a motor assembly **44'** to move the subject longitudinally through the imaging volume **10'** with controlled continuous movement. A tachometer **52'** measures the patient velocity and provides such patient velocity signals to the electronic control and imaging means **B'** to shift the selected slice in the coordinate system of the gantry in accordance with patient movement such that the slice remains fixed in the coordinate system of the patient.

Claims

1. A magnetic resonance apparatus comprising: a patient receiving region; a main magnetic field means (12) disposed around the patient receiving region for generating a main magnetic field which is uniform and temporally constant within an examination volume (10) in the patient receiving region; a radio frequency coil (20) disposed around the examination volume (10); and a patient support and transport means (C) for supporting a patient in the examination volume (10) during a magnetic resonance examination characterised in that the examination volume (10) is thin in a direction parallel to the axis of the patient receiving region;, and the patient support and transport means (C) moves the patient axially through the examination volume (10) during a magnetic resonance examination.

2. An apparatus according to Claim 1 further including a gradient coil assembly (30) disposed around the radio frequency coil (20) for creating gradient magnetic fields along orthogonal directions in the examination volume (10).

3. An apparatus according to Claim 2 further including active gradient shield coils (34) disposed around the gradient coil assembly (30), the gradient coil assembly (30) and the active gradient shield coils (34) acting together gradients in the examination volume (10) and to cancel magnetic field gradients outside of the examination volume (10).

4. An apparatus according to Claim 2 or Claim 3 further including means (24 or 54) for shifting an image slice relative to a coordinate system of the main magnetic field means (12) in coordination with movement of a patient by the patient support and transporting means (C).

5. An apparatus according to any one of Claims 2 to 4 further including: a magnetic resonance imaging sequence memory (24) and control means for designating magnetic field gradient and radio frequency pulses of a selected magnetic resonance imaging sequence; a radio frequency transmitter (22) connected with the sequence memory and control means (24) and the radio frequency coil (20) for transmitting the designated radio frequency pulses into the examination volume (10); a gradient field control means (32) connected with the sequence memory and control means (24) and the gradient coil assembly (30) for causing the gradient coil assembly (30) to create the gradient magnetic fields in the examination volume (10); a radio frequency receiver (26)for receiving radio frequency signals from the examination volume (10) and demodulating the received signals into electronic views; a reconstruction means (28) for reconstructing the views into a three-dimensional image representation; and an image memory (60) for storing the three-dimensional image representation.

6. An apparatus according to Claim 5 wherein the gradient field control means (32) causes the gradient coils (30) to apply at least slice select gradients along the patient receiving region axis and further including: a radio frequency scaling means (54) connected with the radio frequency transmitter (22) and the radio frequency receiver (26) for incrementing resonance frequency in accordance with movement of the patient by the patient support and transport means (C).

7. An apparatus according to Claim 5 or Claim 6 wherein the reconstruction means (28) includes a Fourier transform reconstruction means for reconstructing a plurality of phase-encoded views corresponding to a single slice of an examined subject into a two-dimensional image representation, the sequence memory and control means (24) causing the gradient field control means (32) to index the slice select gradient to a next adjacent slice after the views for each slice have been generated, such that the three-dimensional image representation includes a series of parallel two-dimensional image representations.

8. An apparatus according to Claim 5 or Claim 6 wherein the reconstruction means (28) includes a projection transform reconstruction means for reconstructing a plurality of angularly displaced projection views corresponding to a single slice of an examined subject into a two-dimensional image representation, the sequence

memory and control means (24) causing the gradient field control means (32) to index the slice select gradient to a next adjacent slice after the views for each slice have been generated, such that the three-dimensional image representation includes a series of parallel two-dimensional image representations.

9. An apparatus according to any preceding claim wherein the patient receiving region is cylindrical and wherein the examination volume (10) is a cylinder at least 45 cm in diameter and less than 15 cm thick.

10. An apparatus according to any preceding claim further including an examination volume locating means (80) for moving the main magnetic field means (12), and the radio frequency coil (20), thereby to relocate the examination volume (10).

11. An apparatus according to Claim 10 wherein the examination volume locating means (80) includes a rotating means (86) for rotating the main magnetic field means (12) and the radio frequency coil (20) such that the examination volume (10) can be disposed in a substantially horizontal plane and further including means (88) for moving the examination volume (10) along a vertical axis.

12. An apparatus according to any preceding claim wherein the patient support and transport means (C) includes a patient supporting surface (42), a carriage (40), and a plurality of wheels (70) such that the patient supporting surface (42) and carriage (40) can be wheeled from place to place, whereby one patient can be prepared for the examination in a remote location while another patient is being examined and whereby the patient can be moved from one magnetic resonance apparatus to another.

13. An apparatus according to any preceding claim wherein the main magnetic field means (12) includes a permanent magnet (100) having oppositely disposed pole faces (102) of substantially the width of the examination volume (10'), the examination volume (10') being defined therebetween.

14. A method of magnetic resonance imaging comprising: creating a uniform, temporally constant magnetic field in a thin imaging volume (10); moving a subject through the thin imaging volume (10); while the subject is moving through the imaging volume (10), exciting and manipulating magnetic resonance in a selected slice of the subject that is in the imaging volume (10) and receiving magnetic resonance signals from the selected slice, the imaging volume (10) having a thickness of at least twice the selected slice thickness and less than 15cm in the direction of moving the subject; and reconstructing the magnetic resonance signals from a plurality of slices into an image representation.

15. A method according to Claim 14 wherein the step of exciting and manipulating magnetic resonance and receiving magnetic resonance signals from the selected slice includes applying a slice select gradient along the direction of moving the subject and further including shifting the selected slice relative to the imaging volume (10) such that the selected slice remains substantially fixed relative to the subject.

16. A method according to Claim 15 wherein the selected slice shifting step includes incrementing a frequency of the excited resonance and a demodulation frequency of the received resonance signals.

17. A method according to Claim 16 further including monitoring a cardiac cycle of the subject; and coordinating moving the subject and incrementing the frequency of the excited resonance and the demodulation frequency with the monitored cardiac cycle.

18. A method according to Claim 15, 16 or 17 further including after receiving a full set of magnetic resonance signals from a selected slice for reconstruction into a two-dimensional slice image, indexing the slice select gradient to select a next adjacent slice of the subject and repeating the exciting and manipulating magnetic resonance and receiving magnetic resonance signal step.

19. A method according to any one of Claims 14 to 18 wherein the reconstructing step comprises either Fourier transform reconstruction or projection reconstruction of the magnetic resonance signals into a plurality of parallel two-dimensional slice images.

20. A method according to any one of Claims 14 to 18 wherein the magnetic resonance exciting and manipulating includes applying phase encode gradients which are changed such that the received magnetic resonance signals for a selected slice have a range of phase encoding

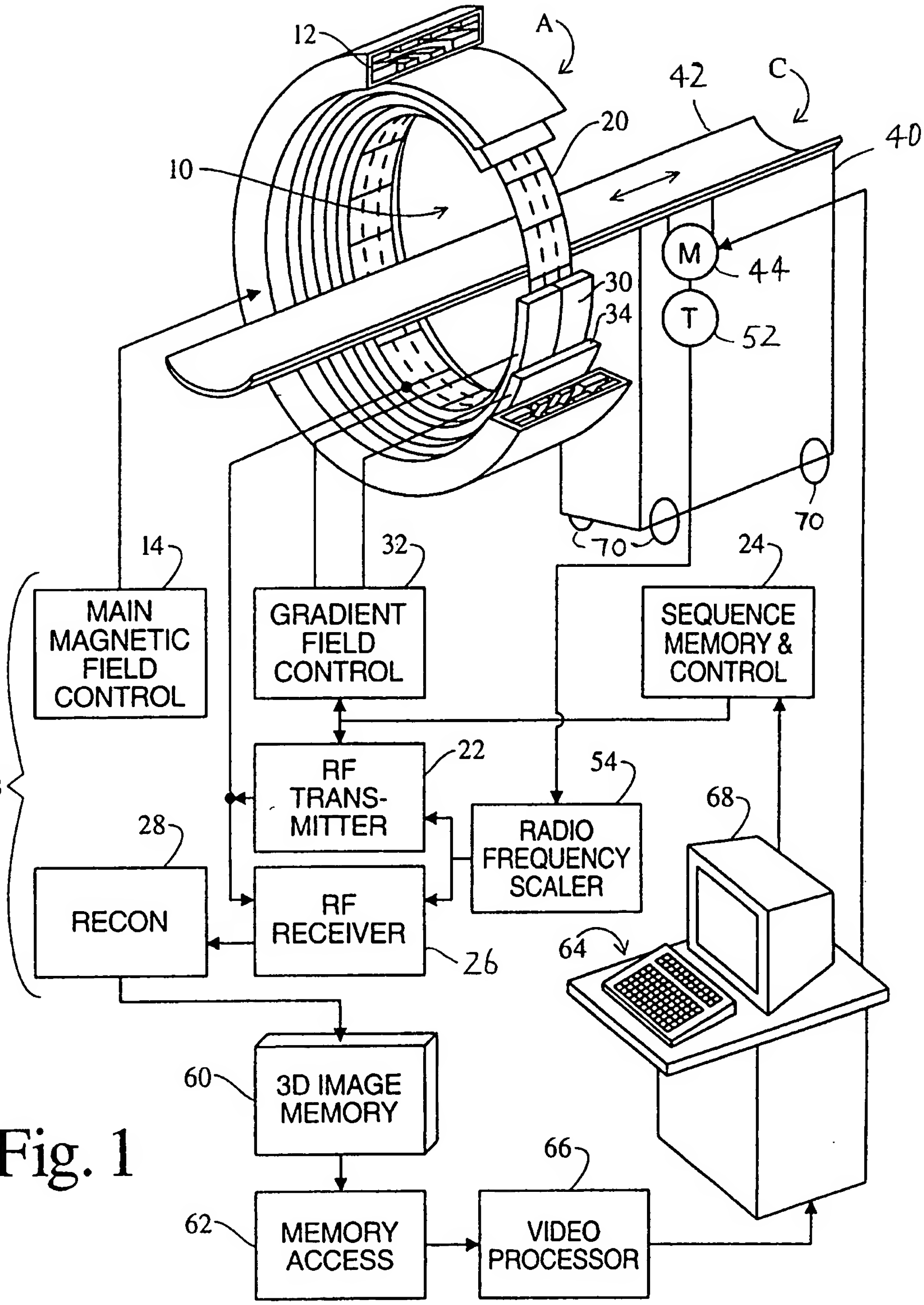
from a central phase encoding to positive and negative high frequency phase encodings on opposite sides of the central phase encoding, the magnetic resonance exciting and manipulating further including applying the positive and negative high frequency phase encoding gradients in temporally contiguous repetitions and applying more central phase encoding gradients in less temporally contiguous repetitions.

21. A method according to Claim 14 wherein the magnetic resonance exciting and manipulating includes applying an echo-planar imaging sequence.

22. A method according to Claim 21 wherein the echo-planar imaging sequence is applied with a repeat time and a resolution such that two-dimensional images of at least six slices are generated per second, whereby substantially real time imaging is provided.

23. A method according to Claim 14 wherein a single one-dimensional projection image of each slice is obtained, the one-dimensional projection images of a multiplicity of slices taken together comprising a two-dimensional shadowgraphic, projection image.

24. A method according to any one of Claims 14 to 22 wherein the magnetic resonance exciting and manipulating includes applying a flow imaging magnetic resonance sequence such that the reconstructed image representation represents flow velocities.


12
A
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34
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MAIN
MAGNETIC
FIELD
CONTROL
GRADIENT
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SEQUENCE
MEMORY &
CONTROL
22
54
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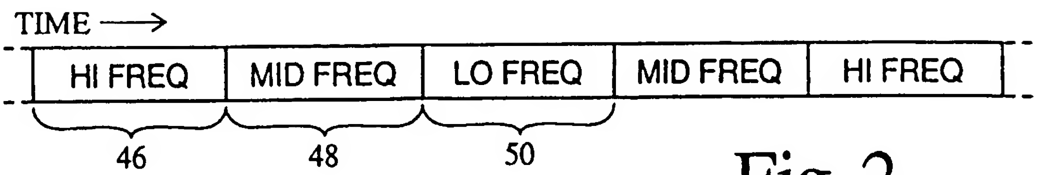
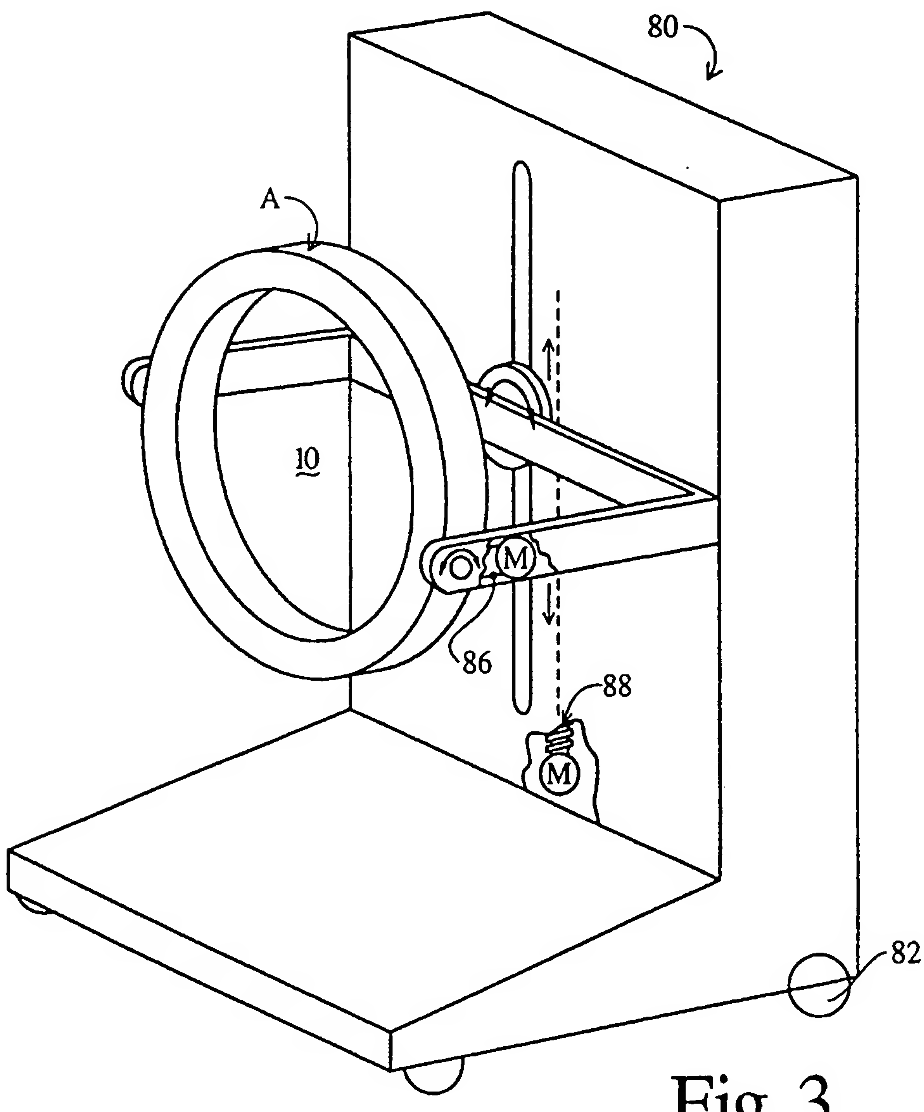
RF
TRANS-
MITTER
68
28
RADIO
FREQUENCY
SCALER
RECON
RF
RECEIVER
26
64
60
3D IMAGE
MEMORY
66
62
MEMORY
ACCESS
VIDEO
PROCESSOR

Fig. 1



TIME
HI FREQ
MID FREQ
LO FREQ
MID FREQ
HI FREQ
46
48
50

Fig. 2



80
A
10
M
86
88
M
82

Fig. 3

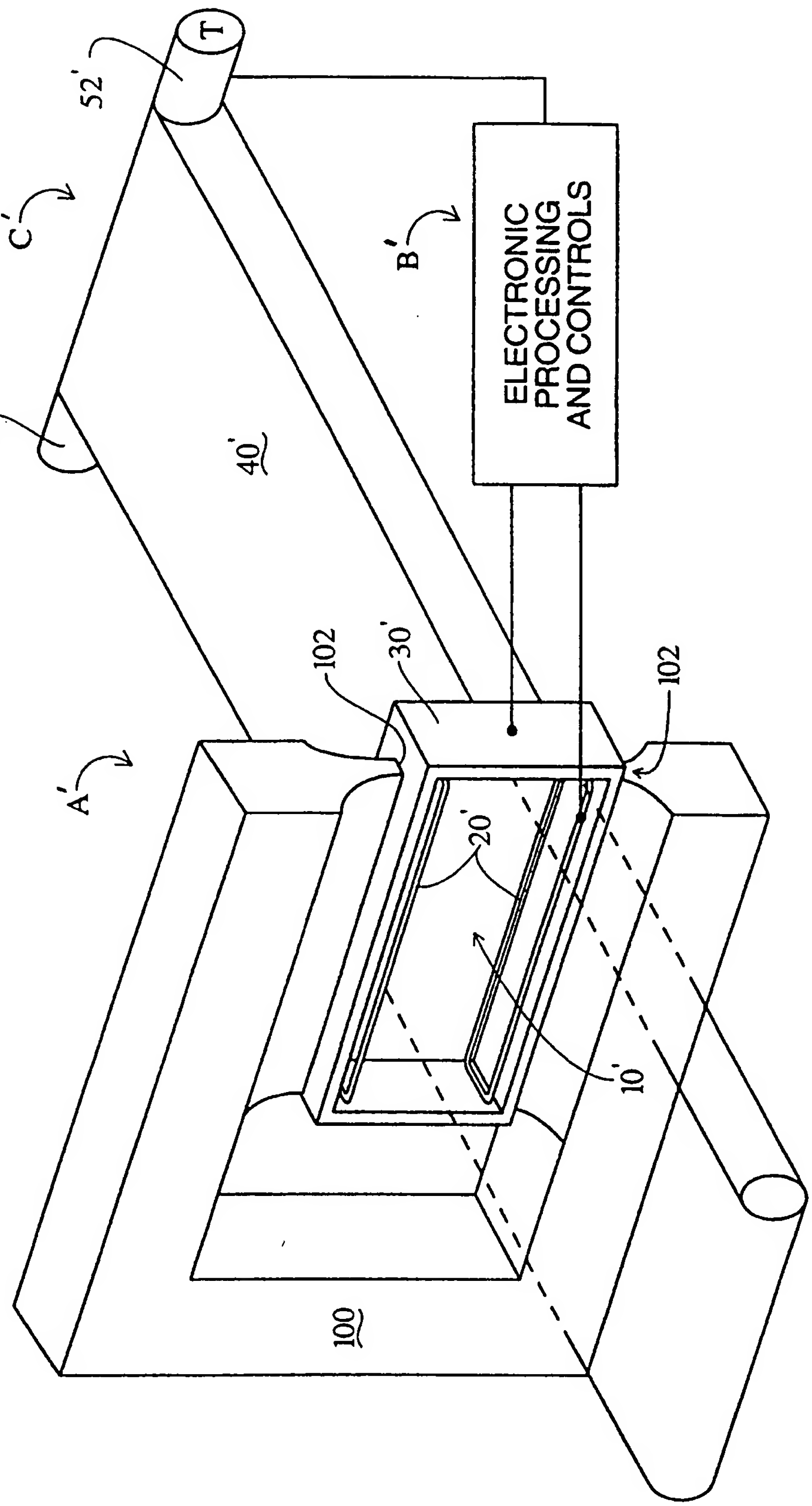

ELECTRONIC PROCESSING AND CONTROLS
T
52'
C'
B'
44'
40'
102
30'
102
A'
20'
20
10'
100

Fig. 4

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 94 30 7885

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	DE-A-36 39 140 (KABUSHIKI KAISHA TOSHIBA) * column 3, line 1 - column 4, line 40 * * column 10, line 15 - column 11, line 1; figures 1,4,6,9 *	1	G01R33/28 G01R33/48 A61B5/055
Y		14	
A		2,4,5, 9-11,15	
Y	PATENT ABSTRACTS OF JAPAN vol. 13, no. 111 (C-577) (3459) 16 March 1989 & JP-A-63 286 142 (TOSHIBA CORP.) 22 November 1988 * abstract *	14	
A		1,13	
A	EP-A-0 430 322 (N.V. PHILIPS' GLOEILAMPENFABRIEKEN) * abstract * * column 3, line 24 - column 8, line 12 *	1,2,4,5, 14	
A	GB-A-2 101 327 (SIEMENS AG) * abstract * * page 1, line 68 - page 2, line 70 *	1,2,4,5, 14	TECHNICAL FIELDS SEARCHED (Int.Cl.6) G01R A61B
A	US-A-4 985 678 (R.E. GANGAROSA ET AL.) * column 1, line 40 - column 2, line 51; figures 1,2 *	1,14	
A	WO-A-92 06386 (SRI INTERNATIONAL) * page 2, line 28 - page 4, line 27 * * page 15, line 29 - page 18, line 20 *	1,14	
A	EP-A-0 314 262 (THE REGENTS OF THE UNIVERSITY OF CALIFORNIA) * abstract * * column 5, line 54 - column 6, line 55 *	1,14	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	10 February 1995	Horak, G

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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